Assessment of Fish, Blue Crab, and Pink Shrimp Mortality in the Tidal Portion of the Alafia River Following the December 1997 Process Water Spill

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Introduction

On December 7, 1997, approximately 60 million gallons of acidic process water spilled into Skinned Sapling Creek, a tributary of the Alafia River, from the Mulberry Phosphate, Inc., facility in Mulberry, Florida. The pH of the spilled water was between 1.8 and 2.0, and pH readings in the creek were as low as 2.24 on December 8, 1997. The acidic plume proceeded downriver and passed through the area of the U.S. 41 bridge (Fig. 1), approximately 64 km from the spill and 1.7 km from the river mouth, on December 11 and 12, 1997. River water in this area is generally neutral to alkaline, 95% of pH values ranging from approximately 7 to 9 (n = 400 observations), but became markedly acidic, pH less than 4, with the passage of the plume. The pH reduction was accompanied by a large fish kill that extended from the spill site to near the river mouth.

This assessment is a compilation of data gathered by several entities before and after the spill. Data sources fall into three categories: 1) smaller-animal seine and trawl data, 2) larger-animal visual survey data, and 3) larger-animal cleanup data. Smaller-animal seine and trawl data were collected by the Florida Department of Environmental Protection, Florida Marine Research Institute, Fisheries-Independent Monitoring

document recovery of the smaller-animal community through February 1998. This document is a revision of earlier drafts based on comments by FGFC, FDEP, MPI, and NOAA.

Methods

Coverage Area: The data presented in this report apply only to the lower, tidally-influenced portion of the Alafia River (Fig. 1). In order to standardize terminology and to facilitate comparisons among studies with differing areal coverages, the river was divided into the following six segments (proceeding upriver from the mouth): segment 1--from the river mouth upstream to near the southeast end of the U.S. highway 41 bridge; segment 2--from the southeast end of the U.S. highway 41 bridge to ~1.9 km upstream of that bridge; segment 3--from ~1.9 km upstream of the U.S. highway 41 bridge to ~0.3 km downstream of the Interstate 75 bridge; segment 4--from ~0.3 km downstream of the Interstate 75 bridge to ~1.4 km upstream of that bridge; segment 5--from ~1.4 km upstream of the Interstate 75 bridge to river km 9.9; segment 6--from river km 9.9 upstream to km 13.1. Segments 1-4 (<12% of the river length from the mouth to the spill site) comprise the area covered by the smaller-animal seine and trawl data, and segments 1-6 (<20% of the river length from the mouth to the spill site) comprise the area covered by the larger-animal visual survey data. The total area covered by the larger-animal cleanup data is not certain, based on the information presented by Langford (in Amundsen and Moore [draft]), but apparently SWS efforts extended upstream to approximately river km 16 (making our entire study area <25% of the river length from the mouth to the spill site).

which are not associated with the shoreline and have water depths greater than 1.0 m are part of the trawl stratum. Prior to each sampling event, the sites to be visited on the Alafia River were randomly selected, without replacement, from all microgrids within each stratum (i.e.: seine and trawl). Segments were only used to identify and locate microgrids; sampling sites were not stratified by segment.

Sampling in the rivers of the Tampa Bay system was conducted seasonally (Spring=March-June, Fall=September-November) from 1989 through 1995; however, before 1994, only one river (Alafia, Little Manatee, or Manatee) was sampled each season. In 1994 and 1995, the Alafia River was sampled once per season, and from 1996 to present the Alafia River was sampled once per month. Supplementary sampling at randomly selected sites was conducted on December 12, 1997, near the time when the low-pH plume passed through segments 1-4. Routine monthly sampling was conducted the following week (December 18, 1997) and in January and February, 1998. Supplementary sampling at randomly selected sites was conducted in February 1998 to help assess the recovery of the river's fish, shrimp, and crab populations.

Samples were collected with a 21.3-m x 1.8-m, 3.2-mm-stretched-mesh seine and a 6.1-m, 38-mm-stretched-mesh otter trawl with a 3.2-mm-stretched-mesh codend liner. Seines were set in a semicircle along the shoreline from a boat, and each set sampled a bottom area of ~68 m^2. Trawls were towed into the current (upstream for all samples collected on Dec. 12, 1997) in deeper water (>1.0 m) at approximately 1 knot for five minutes. Starting and ending positions (latitude and longitude) for each trawl were recorded with LORAN or a Global Positioning System (GPS). The distance

1.34 percent live animals, respectively (Figure 3). Although it is likely that the animal mortality event in segment 1 was not complete prior to the December 12th sampling event, it is also likely that the physical profile of this segment minimized the effect of the acidic plume. Segment 1 has been extensively dredged to provide access to oceangoing freight vessels, thereby greatly increasing its water volume, tidal flushing, and salinity (mean salinity 6.2 ppt in segment 1 versus 4.1-0.3 ppt in segments 2-4 on December 12, 1998). It seems reasonable that with this increased water volume, salinity, and tidal flow, the plume would have been diluted and neutralized more quickly in this segment than in the other three segments. For these reasons, smaller-animal mortality in segment 1, as compared with the upstream segments (2-4), was assumed to be minimal. Although smaller-animal mortality estimates that include segment 1 have been prepared and are included in Appendices A and B of this report, the smaller-animal mortality estimates presented within the report are based on the data collected from segments 2 through 4. Throughout the remainder of this report we will refer to segment 1 as "downstream" and the segment 2-4 combination as "upstream".

Simple-random and stratified-random sampling estimates of smaller-animal populations were calculated from the DEP/FIM program data. Simple-random sampling estimates of mortality (Sokal and Rohlf, 1981) were calculated as:

$$\bar{y} = \frac{\sum y}{n}$$ Estimate of the population mean

$$s = \sqrt{\frac{\sum (y - \bar{y})^2}{n-1}}$$ Estimate of the population standard deviation

spill (December 18, 1997) and prior to the spill (November 20, 1997) to estimate mortality. The subtraction method, which was detailed in the original draft report (May 27, 1998), will not be presented here since separating population changes due to temporal differences from actual mortality due to the spill proved to be difficult. The second method of estimating mortality, the observed mortality method, is based upon the population estimate for dead animals collected in seines and trawls on December 12, 1997. Mortality estimates based upon the stratified-random sampling calculations are used throughout the text to report the smaller-animal mortality, although both simple-random and stratified-random mortality estimates are presented in Appendices A-D. Figures documenting the spill's effect and the Alafia River's subsequent recovery are presented, by stratum (seines and trawls), using simple-random sampling means and standard errors.

Larger-animal Visual Survey Methods: Areal and temporal coverage and count methodology differed among the five entities conducting visual surveys (Table 3; Fig. 4; see Appendix E for descriptions of the exact methodology used and Appendices F-J for raw data from the various surveys). All counts were conducted between 11 and 14 December, 1997, near the time the low pH plume passed through the study area. Counts conducted by LAQ and ESP were not used in total mortality extrapolations because the distance covered and the exact methodology employed by LAQ are not clear based on the documentation they have provided and because ESP counted only one 45.7-m (150 ft) transect. These data, however, were used in comparisons of species composition among sites and investigators.

we did use were designed to represent 3.2 km (2 miles) of river, and we calculated the expansion factor as follows:

$$3.2 \text{ km} \div (4 \times 0.091 \text{ km}) = 8.8 \text{ (rounded to the nearest 0.1).}$$

Larger-animal Cleanup Data: The number of fish removed from the river by SWS was estimated based on a subsample of these fish that was identified, measured, and weighed by FGFC (Appendix K). Langford (in Amundsen and Moore [draft]) suggested using average weights to estimate the number of fish represented by the 4,844.4 kg (5.34 tons) of fish that were removed, but he did not have weights of these fish. Instead he presented an estimate based on the average weight of individuals in a sample he collected from the river, but he also cautioned that the SWS cleanup may have concentrated on larger fishes. We developed what we believe to be a somewhat more accurate estimate of the total number of fish removed in the cleanup operation by using the percent composition and average weight of each species in the FGFC subsample as follows:

$$p_A \times \text{total wt} = \text{total}_{wtA}$$

and

$$\text{total}_{wtA} \div \bar{x}_{wtA} = \text{total}_A$$

where p_A = proportion of the weight of the FGFC subsample comprised by species A, total wt = total weight of fish removed from the river, total_{wtA} = estimated total weight of species A removed from the river, $\bar{x}_{wtA}$ = mean weight of species A in FGFC subsample,

nomenclature was inconsistent among data sets. Because these naming conventions sometimes combine species with quite different direct economic values (e.g., channel catfish, white catfish, and brown bullhead all combined under the name bullhead catfish), we present a species-specific mortality estimate for larger sunfish, bullhead catfish, and gar. This estimate is based on the percentage-composition of the SWS cleanup operation subsample examined by FGFC and is based on the assumption that the species composition in the cleanup subsample was representative of that in the entire study area.

Results and Discussion

Smaller-animal Seine and Trawl Data, Initial Mortality:

Results. Estimates of dead animals within the "upstream" FDEP/FIM sampling area (river segments 2-4) based on seine and trawl data are (rounded to the nearest 100 individuals) ~194,700-2,294,900 (mean ≈ 1,244,800) individuals based on the observed mortality method (Table 8). Most smaller-animal mortality that we detected was "upstream" (Fig. 5), and mean catch rates (CPUE) for dead animals "upstream" were similar in the river channel (represented by trawl data) and along the shoreline (represented by seine data)(mean ≈ 72 and 51 animals per 100 m^2, respectively). Mean catch rates for live animals in seines strongly declined both "upstream" and "downstream" after the spill as compared to the November 1997 values. Mean catch rates for live animals in trawls strongly declined in the "upstream" area as compared to the November 1997 values (Fig. 5) .

trawl after the spill (Appendix D).

Among the more economically valuable species in the river, the two crustaceans, pink shrimp and blue crabs, seemed least affected by the spill. The abundance of pink shrimp was low "upstream" before the spill, but some dead specimens were found "upstream" after the spill (Fig. 10; Table 8). Live pink shrimp were abundant in the river channel "downstream" after the spill. In November 1997, the majority of blue crabs were found in the river channel in the "upstream" portion of the river (Fig. 11). After the spill, live blue crabs appeared to congregate in the "downstream" portion of the river, with the only dead blue crabs taken in "upstream" hauls.

A large number of sheepshead and striped mojarras were included among the observed mortalities (Figs. 12 and 13, Table 8). The only sheepshead caught in seines were dead specimens collected after the spill, and the only striped mojarras caught in trawls were dead specimens collected after the spill.

Two of the more popular recreationally important species, red drum and common snook, also suffered some mortality after the spill (Fig. 14). Both species were relatively abundant in "upstream" shoreline habitats prior to the spill, but populations were greatly reduced after the spill. Red drum were also relatively abundant "downstream" before the spill with an apparent decline in abundance afterwards. Dead red drum and common snook were only collected "upstream" immediately following the spill.

Discussion. There are some complicating factors involved in deriving total mortality estimates by the observed mortality method:

estimates somewhat conservative.

5) One might question whether dead animals are normally present in seine and trawl samples. This would obviously complicate any estimates of spill-induced mortality based on the observed mortality method. We do not believe that this is a problem in our analysis because dead animals are not normally present in FDEP/FIM seine and trawl samples (Fig. 15).

Larger-animal Visual Surveys:

Results. The species composition of larger dead animals was similar among the five visual surveys (Table 9). Striped mojarras and sheepshead were generally the most abundant species with gar, sunfish, ladyfish, common snook, largemouth bass, bullhead catfish, and tilapia also being prominent in some of the surveys. These species are either freshwater fish that often enter the low-salinity portion of estuaries or estuarine/marine fish that often enter low-salinity or even freshwater areas.

We estimated larger-animal mortality (to the nearest 100 individuals) to be ~3,500 for the FGFC survey (segments 1, 4, and 5 on December 11), ~11,500 for the FDEP survey (segments 1-4 on December 11), and ~57,900 for the MES survey (segments 1-6 on December 12-14). The highest observed mortality was in segments 3 and 4 on December 13th (Table 10). This high mortality applies to all species combined and to many individual species. Total estimated mortalities based on the MES data are dominated by striped mojarra, gar, sheepshead, and hardhead catfish (Table 11).

surveys were conducted (bias=underestimate), and 4) SWS was removing dead animals from the river at the same time that the surveys were being conducted (bias=underestimate). Seine and trawl data and the observations of various workers confirm that the first three factors affected counts, but the magnitude of these effects cannot be determined. We attempt to estimate the magnitude of the fourth effect below (larger-animal cleanup data).

Larger-animal Cleanup Data:

Results. We estimate that ~15,000 fish were removed from the river during the cleanup operations conducted by SWS (Table 13). Most of the fish removed were mojarra (presumably striped mojarra), sheepshead, gar, common snook, and tilapia.

Discussion. Our estimate of animals removed by the cleanup operations is very close to that provided by Langford (in Amundsen and Moore Draft). Langford estimated ~12,400 fish based on the average weight of all specimens (all species included) in a sample that he removed from the river. We believe that our estimate should be somewhat more accurate because we used the percentage composition and average weight for each species in a subsample actually taken from the cleanup operations.

Smaller-Animal Seasonality and Recovery:

Results. Fish, pink shrimp, and blue crab abundances for the two-month window following the spill (January-February 1998) were depressed in segments 2-4, the portion of the FDEP/FIM sampling universe that was most affected by the spill (Fig. 16). This trend is pronounced regardless of whether comparisons are made with values for the same period during 1996 or 1997. Species composition of this community also

The January-February numbers of gobies and blue crabs in 1998 were both similar to those in 1996 but were somewhat lower than those in 1997 (Fig. 21). For gobies, both the spill and recovery periods are normally times of low abundance, but blue crab numbers are generally increasing between November-December and January-February, attaining an eventual peak in May-June (Fig. 22).

Two mojarras, eucinostomus and striped mojarra, had recovered to levels at least intermediate between the two previous years in January-February 1998 (Fig. 23). Eucinostomus numbers are quite variable on a bimonthly basis (perhaps bimodal; Fig. 24) and between January-February 1996 and January-February 1997. The spill occurred at a time of peak abundance for striped mojarras, but their numbers generally drop by January-February (Fig. 24).

Striped mullet and spot are both examples of species that do not normally recruit to the river until after November-December, the period during which the spill occurred, and both species were apparently recruiting strongly by January-February 1998 (Figs. 23 and 24).

In the channel only three species were abundant enough in January-February to warrant study. Bay anchovy populations were depressed in January-February 1998 (Fig. 25), and this is a period when bay anchovies are usually quite abundant in the river channel (Fig. 26). Hogchoker and blue crab numbers varied widely (and in the same direction) between 1996 and 1997, and 1998 numbers were intermediate (Fig. 25). Abundances of both species in the channel are usually low to moderate in both the spill and recovery periods but might usually be expected to increase by March-April

The majority of the these animals were schooling, planktivorous fishes that are critical to ecosystem function. Among the species of direct commercial or recreational interest, we estimate that 2,000 or more individuals of the following species (or species groups) were killed: striped mojarra, sand seatrout, bullhead catfish, blue crab, sheepshead, sunfish, pink shrimp, and common snook.

Recovery was evident by January-February 1998, but the populations of the numerically dominant schooling planktivores remained depressed. Most species that are normally abundant in January-February were back in the river in normal or near-normal numbers and some species that normally recruit after the time of the spill were present in large numbers. FDEP/FIM will continue to assess the recovery of fish and crustacean populations in the Alafia River during the spring and summer of 1998.

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Table 2. Sample sizes for FDEP/FIM smaller-animal seine and trawl data base used in mortality calculations.

Segment	November 20, 1997	December 12, 1997	December 18, 1997	Total
		--21.3-m seine--		
1	1	3	1	5
2	2	4	3	9
3	2	3	1	6
4	1	4	1	6
Total	6	14	6	26
		--6.1-m trawl--		
1	0	1	0	1
2	0	1	1	2
3	2	1	0	3
4	0	2	1	3
Total	2	5	2	9

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Table 4. Expansion factors used to calculate mortality based on FDEP/FIM larger-animal visual surveys. Shoreline lengths were rounded to the nearest 10 m prior to calculations, but all digits retained in intermediate calculations. Expansion factors are rounded to the nearest 0.1.

Segment	Shoreline (m)	0.5 times island shoreline (m)	Total shoreline(A)	Number of counts X 100 m (B)	Expansion factor: A/B
1 N shore	2,900	0	2,900	300	9.7
1 S shore	2,060	0	2,060	300	6.9
2 N shore	3,840	685	4,525	100	45.3
2 S shore	5,900	685	6,585	500	13.2
3 N shore	3,330	630	3,960	100	39.6
3 S shore	6,130	630	6,760	100	67.6
4 N shore	2,860	0	2,860	100	28.6
4 S shore	2,110	0	2,110	100	21.1
Total	29,130	2,630	31,760	1,600	

Table 6. Expansion factors used to calculate mortality based on MES larger-animal visual surveys conducted using the AFS wide-stream protocol.

Transect	Segment	Segment Area (m^2) (A)	Transect Width (m)	Transect Length (m)	Transect area (B)	Expansion Factor: A/B
5	1		6.4	260	1,664.0	
15	1		6.4	360	2,304.0	
25	1		6.4	140	896.0	
	1	418,000			4,864.0	85.9
56	2	829,300	6.4	270	1,728.0	479.9
36	3		6.4	280	1,792.0	
46	3		6.4	480	3,072.0	
	3	575,300			4,864.0	118.3
26	4	350,200	6.4	130	832.0	420.9
1	5		6.4	50	320.0	
6	5		6.4	50	320.0	
16	5		6.4	130	832.0	
		371,700			1,472.0	252.5

Table 8. Estimates of fish, blue crab, and pink shrimp mortality after the spill on the Alafia River in December 1997 based on the observed mortality method and stratified-random sampling means and standard errors (stderr). Species included are the ten most abundant species among dead specimens in either seines or trawls plus pink shrimp, longnose gar, kingfish, ladyfish, red drum, common snook, and tilapia due either to their economic value or their prominence among species in visual surveys. min = mean - 1 stderr; max = mean + 1 stderr.

Species	Observed Mortality		
	min	mean	max
All Species	194,705	1,244,791	2,294,878
bay anchovy	133,179	1,107,745	2,082,311
hogchoker	25,111	48,292	71,473
menidia	10,707	19,465	28,223
striped mojarra	9,904	13,358	16,812
sand seatrout	1,854	8,965	16,075
bullhead catfish	1,365	6,385	11,404
rainwater killifish	2,417	4,954	7,492
blue crab	1,013	4,878	8,742
gobiosoma	2,159	4,113	6,067
sheepshead	1,897	3,783	5,670
sunfish	1,128	3,662	6,195
gulf killifish	142	3,013	5,883
pink shrimp	71	2,941	5,810
eucinostomus	609	2,369	4,128
sheepshead minnow	1,047	2,107	3,167
sailfin molly	432	1,151	1,869
longnose gar	136	718	1,299
ladyfish	197	503	810
kingfish	0	478	956
red drum	70	360	649
common snook	127	288	449
tilapia	104	216	327
other species	1,036	5,047	9,067

Table 10. Larger-animal mortality estimates by survey date and river segment based on visual surveys in the Alafia River after the December 1997 spill. All surveys were conducted near the date on which the low pH plume reached the lower portion of the river (December 11-14). Surveys on the morning of the 11th were conducted by FGFC[1], surveys on the afternoon of the 11th were conducted by FDEP, and surveys on the 12th-14th were conducted by MES. Numbers in bold are the peak estimate for each species or group. See text for explanation of calculations. All estimates are rounded to the nearest ten individuals.

	River Segment/Survey Date												
	1			2		3		4			5		6
Species	11th (am)	11th (pm)	14th	11th (pm)	13th	11th (pm)	13th	11th (am)	11th (pm)	13th	11th (am)	12th-13th	12th-13th
striped mojarra	90	70	600	960	2,400	3,330	10,770	250	1,860	**12,210**	690	1,260	0
sheepshead	0	30	0	250	0	710	**2,600**	40	480	2,100	750	510	0
gar	20	30	430	50	0	210	590	40	160	**2,950**	110	2,020	210
hardhead catfish	0	0	0	0	0	70	**1,420**	0	90	1,260	0	0	0
blue crab	0	0	90	0	480	40	**710**	0	0	420	0	250	0
sunfish	20	0	0	0	0	0	120	0	60	**840**	270	760	190
bullhead catfish	0	0	0	0	480	200	240	80	110	**840**	160	250	110
tilapia	0	0	0	30	0	0	240	0	0	420	270	**510**	0
striped mullet	0	20	0	30	0	160	350	0	30	**420**	0	0	0
suckermouth catfish	0	0	0	0	0	0	0	0	0	420	0	**760**	40
common snook	0	40	170	180	**960**	250	240	40	270	0	270	250	0
American eel	0	0	0	0	0	0	120	0	0	0	0	**250**	20
eucinostomus	0	0	0	0	0	0	0	0	0	**420**	0	250	0

Continued.

Table 11. Mortality estimates based on larger-animal visual surveys conducted by MES.

Species	River Segment						Total
	1	2	3	4	5	6	
striped mojarra	601	2,400	10,765	12,206	1,263	0	27,235
gar	430	0	592	2,946	2,020	211	6,199
sheepshead	0	0	2,603	2,105	505	0	5,213
hardhead catfish	0	0	1,420	1,263	0	0	2,683
blue crab	86	480	710	421	253	0	1,950
bullhead catfish	0	480	237	842	253	106	1,918
sunfish	0	0	118	842	758	194	1,912
common snook	172	960	237	0	253	0	1,622
suckermouth catfish	0	0	0	421	758	44	1,223
ladyfish	86	960	118	0	0	0	1,164
tilapia	0	0	237	421	505	0	1,163
striped mullet	0	0	355	421	0	0	776
eucinostomus	0	0	0	421	253	0	674
gizzard shad	0	0	0	421	253	0	674
spotted seatrout	86	480	0	0	0	0	566
largemouth bass	0	0	0	0	505	18	523
Atlantic needlefish	0	480	0	0	0	0	480
gulf toadfish	0	480	0	0	0	0	480
southern stingray	0	480	0	0	0	0	480
crevalle jack	0	0	0	421	0	0	421
American eel	0	0	118	0	253	18	389
red drum	0	0	118	0	0	0	118
Total	1,461	7,200	17,628	23,151	7,832	591	57,863

Table 13. Fish removed from the Alafia River by SWS based on subsample examined by FGFC (see Appendix K). Total weight applies to all specimens removed from the river by SWS.

Species	Proportion of subsample wt. (A)	total weight (kg) (B)	total wt. of species ([A × B] = C)	av. wt. in subsample (kg) (D)	number of individuals (total wt./av. wt.) (D ÷ C)
common snook	0.1123	4,844.40	544.03	0.86	632.59
hardhead catfish	0.0161	4,844.40	77.99	0.32	243.73
largemouth bass	0.0403	4,844.40	195.23	1.05	185.93
bluegill	0.0019	4,844.40	9.20	0.04	230.11
redear sunfish	0.0027	4,844.40	13.08	0.14	93.43
spotted sunfish	0.0015	4,844.40	7.27	0.08	90.83
tilapia	0.0537	4,844.40	260.14	0.61	426.47
channel catfish	0.0671	4,844.40	325.06	1.94	167.56
white catfish	0.0180	4,844.40	87.20	0.59	147.80
brown bullhead	0.0038	4,844.40	18.41	0.50	36.82
gizzard shad	0.0150	4,844.40	72.67	0.65	111.79
mullet	0.0314	4,844.40	152.11	0.41	371.01
red drum	0.0069	4,844.40	33.43	0.36	92.85
spotted seatrout	0.0015	4,844.40	7.27	0.20	36.33
black drum	0.0050	4,844.40	24.22	1.30	18.63
ladyfish	0.0165	4,844.40	79.93	0.31	257.85
sheepshead	0.0441	4,844.40	213.64	0.17	1,256.69
mojarra	0.2588	4,844.40	1,253.73	0.13	9,644.08
longnose gar	0.2446	4,844.40	1,184.94	1.68	705.32
Florida gar	0.0023	4,844.40	11.14	0.60	18.57
sailfin molly	0.0000	4,844.40	0.19	0.01	19.38
gafftopsail catfish	0.0104	4,844.40	50.38	1.35	37.32
suckermouth catfish	0.0077	4,844.40	37.30	0.50	74.60
grunt	0.0008	4,844.40	3.88	0.20	19.38
gulf toadfish	0.0004	4,844.40	1.94	0.05	38.76
spadefish	0.0035	4,844.40	16.96	0.45	37.68
common carp	0.0176	4,844.40	85.26	4.60	18.54
butterfly ray	0.0153	4,844.40	74.12	4.00	18.53
Atlantic croaker	0.0008	4,844.40	3.88	0.10	38.76
Total	1.0000				15,071.33

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Appendix B. Simple-random estimates of fish, blue crab, and pink shrimp mortality in segments 1-4 of the Alafia River following the spill in December 1997. Estimates are based on the observed mortality method and means and standard errors calculated for each stratum (gear) separately. The observed mortality method multiplies the mean number of dead animals present on December 12, 1997 by the area in segments 1-4 (seine area=63,700m²; trawl area=2,109,100m²). Species are listed in alphabetical order by scientific name (the common name is listed to the right in parentheses) and gear.

Gear	Species	December 12, 1997 (dead) Mean A	Stderr B	Mortality Estimate Mean-Stderr (A-B)*Area	Mean A*Area	Mean+Stderr (A+B)*Area
Seine	*Adinia xenica* (diamond killifish)	0.001050	0.001050	0	67	134
Trawl	*Adinia xenica* (diamond killifish)	0.000225	0.000225	0	474	949
Seine	*Anchoa mitchilli* (bay anchovy)	0.066176	0.032254	2,161	4,215	6,270
Trawl	*Anchoa mitchilli* (bay anchovy)	0.519023	0.462374	119,479	1,094,672	2,069,865
Seine	*Archosargus probatocephalus* (sheepshead)	0.031513	0.022754	558	2,007	3,457
Trawl	*Archosargus probatocephalus* (sheepshead)	0.000765	0.000530	494	1,612	2,731
Seine	*Arius felis* (hardhead catfish)	0.001050	0.001050	0	67	134
Seine	*Bairdiella chrysoura* (silver perch)	0.002101	0.001427	43	134	225
Seine	*Bathygobius soporator* (frillfin goby)	0.001050	0.001050	0	67	134
Seine	*Belonesox belizanus* (pike killifish)	0.001050	0.001050	0	67	134
Seine	*Callinectes sapidus* (blue crab)	0.004202	0.001843	150	268	385
Trawl	*Callinectes sapidus* (blue crab)	0.002159	0.001840	672	4,553	8,434
Seine	*Centropomus undecimalis* (snook)	0.004202	0.002402	115	268	421
Seine	*Cynoscion arenarius* (sand seatrout)	0.001050	0.001050	0	67	134
Trawl	*Cynoscion arenarius* (sand seatrout)	0.004182	0.003402	1,645	8,821	15,997
Seine	*Cynoscion nebulosus* (spotted seatrout)	0.001050	0.001050	0	67	134
Seine	*Cyprinodon variegatus* (sheepshead minnow)	0.016807	0.007040	622	1,071	1,519
Trawl	*Cyprinodon variegatus* (sheepshead minnow)	0.000450	0.000450	0	949	1,897
Seine	*Dasyatis sabina* (atlantic stingray)	0.001050	0.001050	0	67	134
Seine	*Diapterus plumieri* (striped mojarra)	0.094538	0.045253	3,139	6,022	8,905
Trawl	*Diapterus plumieri* (striped mojarra)	0.003238	0.001132	4,441	6,829	9,218
Seine	*Elops saurus* (ladyfish)	0.007353	0.004560	178	468	759
Seine	*Eucinostomus* spp. (eucinostomus)	0.009454	0.005474	254	602	951
Trawl	*Eucinostomus* spp. (eucinostomus)	0.000809	0.000809	0	1,707	3,415
Seine	*Floridichthys carpio* (goldspotted killifish)	0.008403	0.005913	159	535	912
Seine	*Fundulus grandis* (gulf killifish)	0.002101	0.001427	43	134	225
Trawl	*Fundulus grandis* (gulf killifish)	0.001349	0.001349	0	2,846	5,691
Seine	*Fundulus majalis* (striped killifish)	0.007353	0.004292	195	468	742
Trawl	*Fundulus majalis* (striped killifish)	0.000270	0.000270	0	569	1,138
Seine	*Fundulus seminolis* (seminole killifish)	0.003151	0.003151	0	201	401
Seine	*Gambusia holbrooki* (eastern mosquito fish)	0.001050	0.001050	0	67	134
Seine	*Gobiesox strumosus* (skilletfish)	0.001050	0.001050	0	67	134
Seine	*Gobiosoma* spp. (gobiosoma)	0.004202	0.001843	150	268	385
Trawl	*Gobiosoma* spp. (gobiosoma)	0.001799	0.000996	1,694	3,794	5,894

Continued

Appendix C. Stratified-random estimates of fish, blue crab, and pink shrimp mortality in segments 2-4 of the Alafia River following the spill in December 1997. Estimates are based on the observed mortality method and stratified-random sampling means and standard errors. The observed mortality method multiplies the mean number of dead animals present on December 12, 1997 by the area in segments 2-4 (area=1,754,800m²). Species are listed in alphabetical order by scientific name (the common name is listed to the right in parentheses).

Species	December 12, 1997 (dead)		Mortality Estimate		
	Mean	Stderr	Mean-Stderr	Mean	Mean+Stderr
	A	*B*	(A-B)*Area	A*Area	(A+B)*Area
Adinia xenica (diamond killifish)	0.000313	0.000276	67	550	1,034
Anchoa mitchilli (bay anchovy)	0.631266	0.555372	133,179	1,107,745	2,082,311
Archosargus probatocephalus (sheepshead)	0.002156	0.001075	1,897	3,783	5,670
Arius felis (hardhead catfish)	0.000041	0.000041	0	72	144
Bairdiella chrysoura (silver perch)	0.000082	0.000055	47	144	240
Belonesox belizanus (pike killifish)	0.000041	0.000041	0	72	144
Callinectes sapidus (blue crab)	0.002780	0.002202	1,013	4,878	8,742
Centropomus undecimalis (snook)	0.000164	0.000092	127	288	449
Cynoscion arenarius (sand seatrout)	0.005109	0.004052	1,854	8,965	16,075
Cyprinodon variegatus (sheepshead minnow)	0.001201	0.000604	1,047	2,107	3,167
Dasyatis sabina (atlantic stingray)	0.000041	0.000041	0	72	144
Diapterus plumieri (striped mojarra)	0.007612	0.001969	9,904	13,358	16,812
Elops saurus (ladyfish)	0.000287	0.000175	197	503	810
Eucinostomus spp. (eucinostomus)	0.001350	0.001003	609	2,369	4,128
Floridichthys carpio (goldspotted killifish)	0.000328	0.000228	175	575	976
Fundulus grandis (gulf killifish)	0.001717	0.001636	142	3,013	5,883
Fundulus majalis (striped killifish)	0.000614	0.000366	435	1,077	1,719
Fundulus seminolis (seminole killifish)	0.000123	0.000123	0	216	432
Gambusia holbrooki (eastern mosquito fish)	0.000041	0.000041	0	72	144
Gobiosoma spp. (gobiosoma)	0.002344	0.001114	2,159	4,113	6,067
Ictalurus spp. (bullhead catfish)	0.003638	0.002861	1,365	6,385	11,404
Lepisosteus osseus (longnose gar)	0.000409	0.000332	136	718	1,299
Lepomis spp. (sunfish)	0.002087	0.001444	1,128	3,662	6,195
Loricariidae spp. (suckermouth catfish)	0.000041	0.000041	0	72	144
Lucania parva (rainwater killifish)	0.002823	0.001446	2,417	4,954	7,492
Menidia spp. (menidia)	0.011093	0.004991	10,707	19,465	28,223
Menticirrhus spp. (kingfish)	0.000272	0.000272	0	478	956
Microgobius gulosus (clown goby)	0.000491	0.000340	266	861	1,457
Microgobius thalassinus (green goby)	0.000272	0.000272	0	478	956
Mugil cephalus (striped mullet)	0.000041	0.000041	0	72	144
Opsanus beta (gulf toadfish)	0.000082	0.000055	47	144	240
Penaeus duorarum (pink shrimp)	0.001676	0.001635	71	2,941	5,810
Poecilia latipinna (sailfin molly)	0.000656	0.000409	432	1,151	1,869
Sciaenops ocellatus (red drum)	0.000205	0.000165	70	360	649
Symphurus plagiusa (blackcheek tonguefish)	0.000327	0.000327	0	574	1,147
Tilapia spp. (tilapia)	0.000123	0.000063	104	216	327
Trinectes maculatus (hogchoker)	0.027520	0.013210	25,111	48,292	71,473
Total (Column Totals)			194,705	1,244,791	2,294,878
Total (Stratified-random sampling means and Stderr)	0.709360	0.582670	222,316	1,244,785	2,267,254

Appendix. D. Continued.

Gear	Species	December 12, 1997 (dead) Mean A	Stderr B	Mortality Estimate Mean-Stderr (A-B)*Area	Mean A*Area	Mean+Stderr (A+B)*Area
Seine	*Lepomis* spp. (sunfish)	0.025401	0.019937	294	1,367	2,439
Trawl	*Lepomis* spp. (sunfish)	0.001349	0.001349	0	2,295	4,590
Seine	*Loricariidae* spp. (suckermouth catfish)	0.001337	0.001337	0	72	144
Seine	*Lucania parva* (rainwater killifish)	0.038770	0.024389	774	2,086	3,398
Trawl	*Lucania parva* (rainwater killifish)	0.001686	0.001277	697	2,869	5,041
Seine	*Menidia* spp. (menidia)	0.040107	0.019337	1,117	2,158	3,198
Trawl	*Menidia* spp. (menidia)	0.010175	0.005112	8,612	17,308	26,004
Trawl	*Menticirrhus* spp. (kingfish)	0.000281	0.000281	0	478	956
Seine	*Microgobius gulosus* (clown goby)	0.005348	0.002989	127	288	449
Trawl	*Microgobius gulosus* (clown goby)	0.000337	0.000337	0	574	1,147
Trawl	*Microgobius thalassinus* (green goby)	0.000281	0.000281	0	478	956
Seine	*Mugil cephalus* (striped mullet)	0.001337	0.001337	0	72	144
Seine	*Opsanus beta* (gulf toadfish)	0.002674	0.001794	47	144	240
Seine	*Penaeus duorarum* (pink shrimp)	0.001337	0.001337	0	72	144
Trawl	*Penaeus duorarum* (pink shrimp)	0.001686	0.001686	0	2,869	5,737
Seine	*Poecilia latipinna* (sailfin molly)	0.021390	0.013356	432	1,151	1,869
Seine	*Sciaenops ocellatus* (red drum)	0.006684	0.005381	70	360	649
Trawl	*Symphurus plagiusa* (blackcheek tonguefish)	0.000337	0.000337	0	574	1,147
Seine	*Tilapia* spp. (tilapia)	0.004011	0.002071	104	216	327
Seine	*Trinectes maculatus* (hogchoker)	0.016043	0.007274	472	863	1,254
Trawl	*Trinectes maculatus* (hogchoker)	0.027883	0.013626	24,251	47,428	70,606
	Total (Column Totals)			185,304	1,244,791	2,304,278
	Total (Seine mean and Stderr)	0.51337	0.11956	21,187	27,619	34,052
	Total (Trawl mean and Stderr)	0.71556	0.60109	194,713	1,217,168	2,239,622

An actual count of 25,000 fish was made by a team of qualified individuals from Langford Aquatics on 12 December 1997. The fish count started at the beginning of the fish kill area approximately 2 miles upstream of the Highway 301 bridge, and proceeded downstream to the booms stretched across the river west of the 301 bridge. Langford Aquatics conservatively added another 12,500 fish to this number for fish that may have been missed in the count and added another 12,418 fish for the number of fish that may have been picked up and disposed before 12 December 1997. Using these conservative assumptions, the fish mortality estimate may be as high as 50,000. Species distribution, species number, and weights were estimated from a representative number of fish collected..."

ESP

The following information is taken from a draft report produced by Amundsen and Moore:

"ESP wildlife ecologist/fisheries scientist conducted sampling on the north side of the U.S. 301 bridge. The sample area was approximately 150 feet by 20 feet. This site was chosen due to its apparent lack of disturbance by predators or humans, and the apparent similarity of fishes observed at other areas. The sampling was conducted 12 December 1997, from 12:30 to 14:00 hours. Fish were weighed using a hand held spring scale. The length was determined by using a yard stick in tenths of inches. The purpose of the survey was to get an idea of the species distribution and size classes that were affected."

MES

The following information is taken from a draft report produced by MES:

"After an initial reconnaissance of the Alafia River on December 12, 1997, it was determined that the area from river mile 0 to river mile 6.2 was suitable for the wide stream protocol. The area from river mile 6.2 to river mile 9.9 (end of tidally influenced area) was determined to be suitable for the narrow stream protocol. The area from mile 6.2 to mile 9.9 was divided to 7 one-half mile segments each of which was to be sampled. The area from mile 6.2 to Highway 41 bridge (mile 1.1) was also divided into 7 sampling segments. A random number table was consulted and the number 1 selected. Team one sampled the first 100 yard segment of the first 1/2 mile (designated T1-1) and team 2 made the first transect of segment 7 (designated 1). The survey was then discontinued due to darkness.

The teams returned to the river on December 13. A random number table was once again consulted and Team 1 again chose the numeral 1 and began

Appendix F. Dead animals counted by FDEP/FIM in the Alafia River on December 11, 1997.

Species	Segment 1	Segment 2	Segment 3	Segment 4	Total
Elops saurus	11	54	4	1	70
Diapterus plumieri	7	29	92	72	200
Cynoscion nebulosus	6	2	0	0	8
Centropomus undecimalis	5	5	9	10	29
Archosargus probatocephalus	3	8	19	18	48
Lepisosteus spp.	2	3	1	1	7
Mugil spp.	2	1	0	0	3
Pogonias cromis	2	2	1	0	5
Sciaenops ocellatus	2	2	0	0	4
Lepisosteus osseus	1	1	3	6	11
Strongylura spp.	1	0	0	0	1
Anchoa spp.[1]	0	2000	20	15	2035
Bairdiella chrysoura	0	6	0	1	7
Tilapia spp.	0	2	0	0	2
Caranx hippos	0	1	0	0	1
Strongylura timucu	0	1	0	0	1
Ictaluridae	0	0	5	4	9
Mugil cephalus	0	0	5	1	6
Arius felis	0	0	1	4	5
Callinectes sapidus	0	0	1	0	1
Cyprinodon variegatus	0	0	1	7	8
Fundulus grandis	0	0	1	5	6
Fundulus majalis	0	0	1	0	1
Dorosoma petenense	0	0	0	1	1
Lepomis punctatus	0	0	0	1	1
Lepomis spp.	0	0	0	1	1
Menidia spp.	0	0	0	1	1
Total	42	2117	164	149	2472

[1]Counts of *Anchoa* spp. were only estimates because floating masses of dead animals were observed in several areas.

Appendix H. Dead animals counted in the Alafia River by MES from 11-14 December, 1997.

Species	Segment						Total
	1	2	3	4	5	6	
Diapterus plumieri	7	24	72	29	5	0	137
Lepisosteus osseus	5	0	5	7	7	18	42
Centropomus undecimalis	2	3	1	0	1	0	7
Callinectes sapidus	1	3	4	1	1	0	10
Elops saurus	1	3	0	0	0	0	4
Cynoscion nebulosus	1	1	0	0	0	0	2
Archosargus probatocephalus	0	4	18	5	2	0	29
Arius felis	0	2	10	3	0	0	15
Opsanus beta	0	1	0	0	0	0	1
Strongylura marina	0	1	0	0	0	0	1
Dasyatis americanus	0	1	0	0	0	0	1
Ictaluridae	0	1	2	2	1	6	12
Eurytium spp.	0	1	0	0	0	0	1
Floridichthys carpio	0	3	1	0	0	0	4
Fundulus grandis	0	1	2	0	0	0	3
Menidia spp.	0	2	0	0	0	0	2
Microgobius gulosus	0	1	0	0	0	0	1
Lucania parva	0	1	0	0	0	0	1
Anguilla rostrata	0	0	1	0	1	2	4
Mugil cephalus	0	0	3	1	0	0	4
Lepomis spp.	0	0	1	2	0	22	25
Tilapia spp.	0	0	2	1	2	0	5
Sciaenops ocellatus	0	0	1	0	0	0	1
Urophycis floridanus	0	0	1	0	0	0	1
Fundulus majalis	0	0	1	0	0	0	1
Poecilia latipinna	0	0	1	1	0	0	2
Caranx hippos	0	0	0	1	0	0	1
Eucinostomus spp.	0	0	0	1	1	0	2
Dorosoma cepedianum	0	0	0	1	1	0	2

Appendix I. Species collected by dipnet by LAQ from the Alafia River near highway 301 (upstream) on December 11, 1997.

Species	Number	% Number
Lepomis macrochirus	15	8.0
Lepomis microlophus	15	8.0
Lepomis gulosus	10	5.3
Micropterus salmoides	10	5.3
Ictalurus punctatus	4	2.1
Fundulus spp.	14	7.5
Tilapia aurea	9	4.8
Ctenopharyngodon idella	1	0.5
Lepisosteus osseus	1	0.5
Dorosoma cepedianum	1	0.5
Centropomus undecimalis	6	3.2
Mugil cephalus	8	4.3
Archosargus probatocephalus	51	27.4
Diapterus plumieri	41	22.0
Total	186	99.4

Appendix K. Subsample of fish from SWS cleanup operations. Data provided by FGFC.

Species	Mean Length (in)	Mean Length (mm)	N	Total Wt. (kg)	Mean Wt. (kg)
Micropterus salmoides	15.50	393.70	10.00	10.50	1.05
Lepomis macrochirus	3.57	90.68	14.00	0.50	0.04
Lepomis microlophus	6.80	172.72	5.00	0.70	0.14
Lepomis punctatus	5.60	142.24	5.00	0.40	0.08
Tilapia melanotheron	10.70	271.78	23.00	14.00	0.61
Ictalurus punctatus	20.22	513.59	9.00	17.50	1.94
Ameiurus catus	12.75	323.85	8.00	4.70	0.59
Ameiurus nebulosus	12.50	317.50	2.00	1.00	0.50
Dorosoma cepedianum	14.33	363.98	6.00	3.90	0.65
Mugil spp.	12.80	325.12	20.00	8.20	0.41
Arius felis	12.54	318.52	13.00	4.20	0.32
Bagre marinus	18.50	469.90	2.00	2.70	1.35
Loricariidae	15.00	381.00	4.00	2.00	0.50
Haemulidae	8.00	203.20	1.00	0.20	0.20
Opsanus beta	5.00	127.00	2.00	0.10	0.05
Chaetodipterus faber	9.50	241.30	2.00	0.90	0.45
Cyprinus carpio	26.00	660.40	1.00	4.60	4.60
Gymnura spp.	20.00	508.00	1.00	4.00	4.00
Micropogonias undulatus	7.00	177.80	2.00	0.20	0.10
Centropomus undecimalis	13.29	337.57	34.00	29.30	0.86
Sciaenops ocellatus	11.40	289.56	5.00	1.80	0.36
Cynoscion nebulosus	10.50	266.70	2.00	0.40	0.20
Pogonias cromis	18.00	457.20	1.00	1.30	1.30
Elops saurus	14.50	368.30	14.00	4.30	0.31
Archosargus probatocephalus	6.94	176.28	68.00	11.50	0.17
Gerreidae	6.43	163.32	524.00	67.50	0.13
Lepisosteus osseus	31.05	788.67	38.00	63.80	1.68
Lepisosteus platyrhinchus	20.00	508.00	1.00	0.60	0.60
Poecilia latipinna	2.00	50.80	2.00	0.01	0.01
Total			**819.00**	**260.81**	
Mean Length of All Species	8.93	226.82			
Mean Weight of All Species				0.32	

Appendix L. (cont.)

Anguillidae

American eel: *Anguilla rostrata*

Engraulidae

bay anchovy: *Anchoa mitchilli*

Clupeidae

gulf menhaden: *Brevoortia patronus*

yellowfin menhaden: *Brevoortia smithi*

--data for these two species are lumped under "menhaden"

gizzard shad: *Dorosoma cepedianum*

threadfin shad: *Dorosoma petenense*

scaled sardine: *Harengula jaguana*

Atlantic thread herring: *Opisthonema oglinum*

Cyprinidae

common carp: *Cyprinus carpio*

grass carp: *Ctenopharyngodon idella*

coastal shiner: *Notropis petersoni*

Catostomidae

lake chubsucker: *Erimyzon sucetta*

Ictaluridae

white catfish: *Ameiurus catus*

brown bullhead: *Ameiurus nebulosus*

channel catfish: *Ictalurus punctatus*

--all *Ameiurus* and *Ictalurus* are lumped under the family common name "bullhead catfish"

tadpole madtom: *Noturus gyrinus*

Loricariidae

suckermouth catfish: *Hypostomus* spp. (?)

--several species in this family have been introduced in Florida waters and the exact identity of Alafia river specimens is uncertain; also known as

Appendix L. (cont.)

sheepshead minnow: *Cyprinodon variegatus*

goldspotted killifish: *Floridichthys carpio*

marsh killifish: *Fundulus confluentus*

gulf killifish: *Fundulus grandis*

striped killifish: *Fundulus majalis* (listed as "*Fundulus similis*" in Mote Environmental Services [draft])

Seminole killifish: *Fundulus seminolis*

bluefin killifish: *Lucania goodei*

rainwater killifish: *Lucania parva*

Syngnathidae

chain pipefish: *Syngnathus louisianae*

gulf pipefish: *Syngnathus scovelli*

Triglidae

leopard searobin: *Prionotus scitulus*

bighead searobin: *Prionotus tribulus*

Centropomidae

common snook: *Centropomus undecimalis*

Centrarchidae

redbreast sunfish: *Lepomis auritus*

warmouth: *Lepomis gulosus* (listed by Amundsen and Moore (1998) as "*Chaenobrythus* [*sic*] *gulosus*")

bluegill: *Lepomis macrochirus*

redear sunfish: *Lepomis microlophus*

spotted sunfish: *Lepomis punctatus*

--data for all species of *Lepomis* are lumped under "sunfish"; "*Lepomis gibbosus*" listed in Mote Environmental Services (draft) is not known from this area although it has been widely introduced elsewhere

largemouth bass: *Micropterus salmoides* ("*Micropterus dolomieui*" listed in Mote Environmental Services [draft] is probably this species because *M.*

southern kingfish: *Menticirrhus americanus*

northern kingfish: *Menticirrhus saxatilis*

--data for all *Menitcirrhus* are lumped under "kingfish"

Atlantic croaker: *Micropogonias undulatus*

black drum: *Pogonias cromis*

red drum: *Sciaenops ocellatus*

--"drum" recorded in the FGFC visual survey are undoubtedly members of this family but cannot be assigned to a particular species

Cichlidae

blue tilapia: *Tilapia aurea*

blackchin tilapia: *Tilapia melanotheron*

--data for these species are lumped under "tilapia"

Blenniidae

Florida blenny: *Chasmodes saburrae*

Gobiesocidae

skilletfish: *Gobiesox strumosus*

Gobiidae

frillfin goby: *Bathygobius soporator*

naked goby: *Gobiosoma bosc*

code goby: *Gobiosoma robustum*

--data for all *Gobiosoma* are lumped under "gobiosoma"

clown goby: *Microgobius gulosus*

green goby: *Microgobius thalassinus*

--data for all species in this family are lumped under "goby" in the "Smaller Animal Seasonality and Recovery" portion of this report

Ephippidae

Atlantic spadefish: *Chaetodipterus faber*

Bothidae

flounder: *Etropus* spp.

List of Figures

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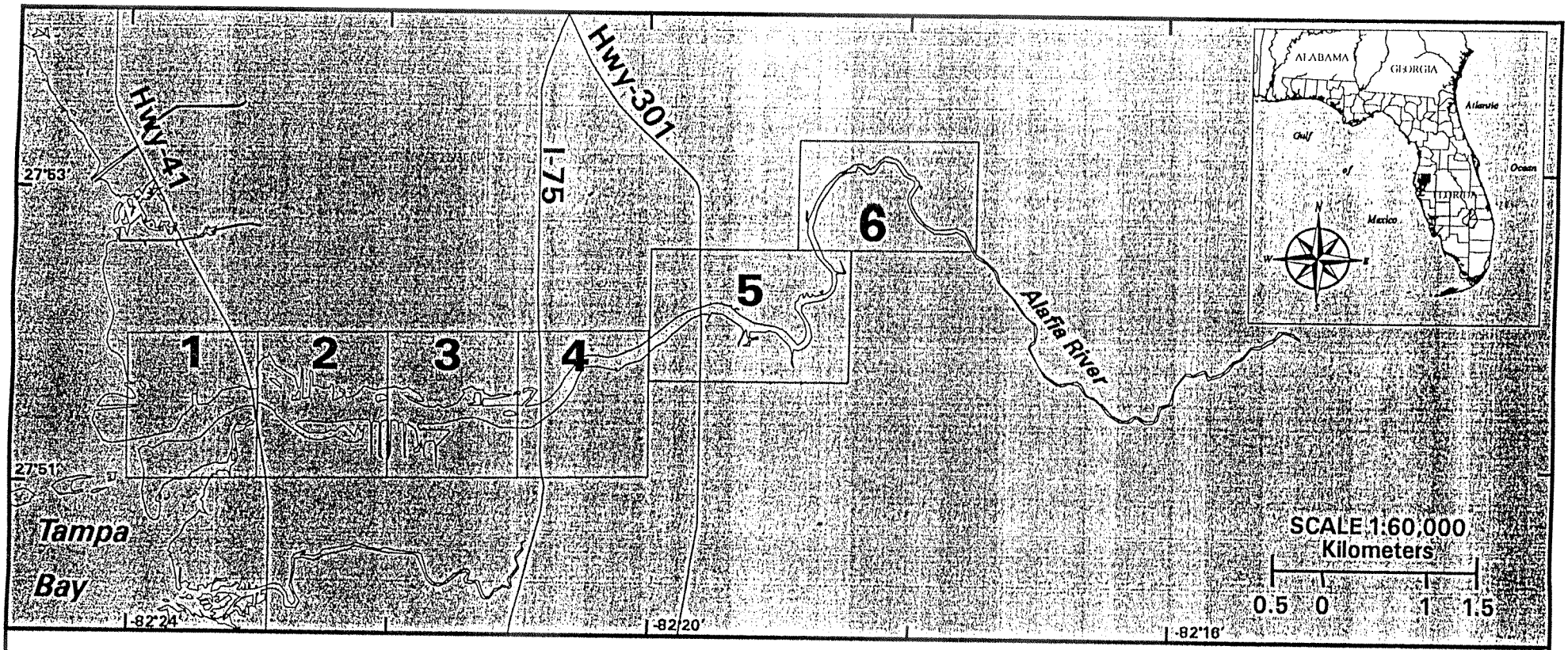

Figure 1. Alafia River study area. Numbered boxes indicate river segments associated with mortality estimates.

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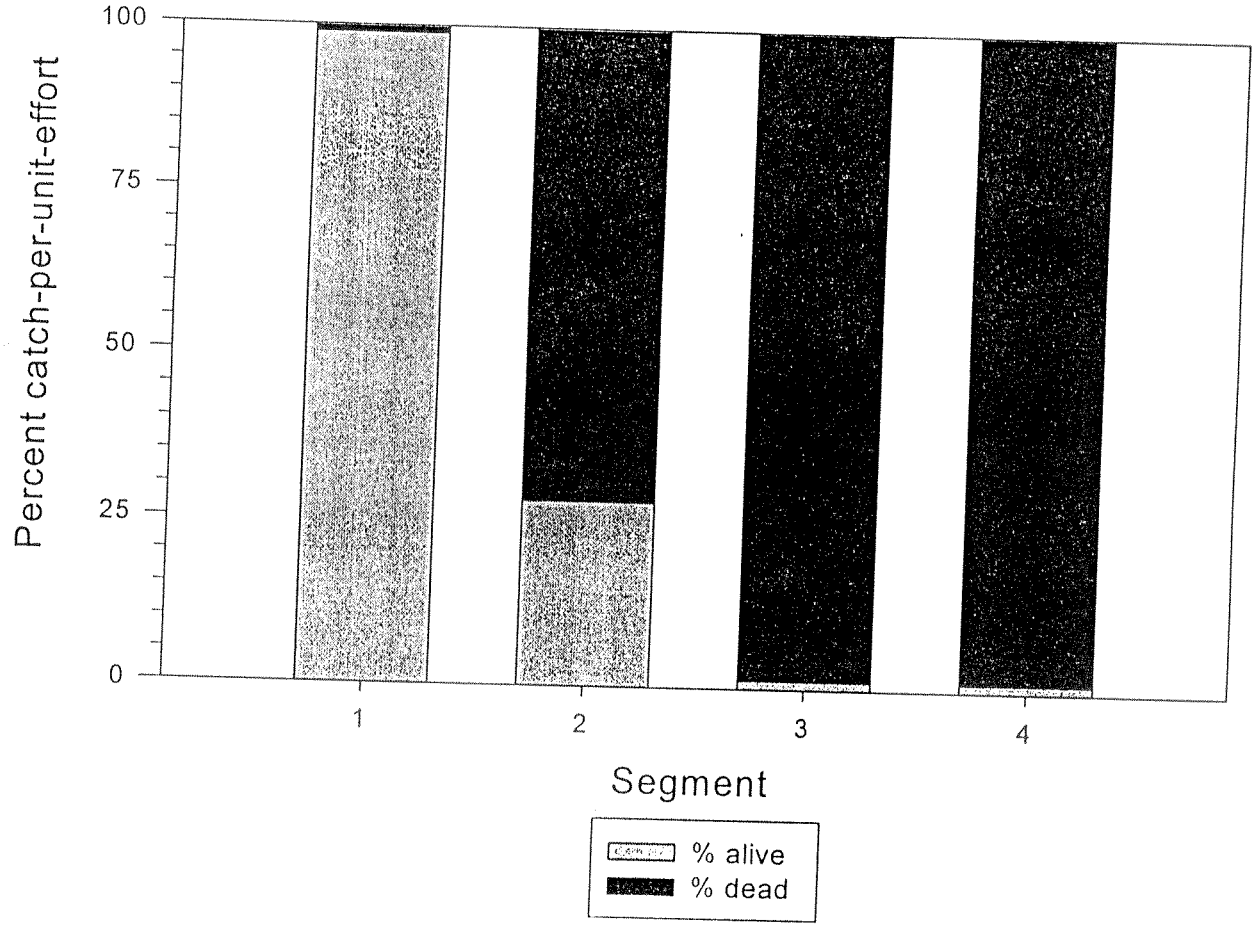

Figure 3. Percent catch-per-unit-effort (SRS means) of live and dead animals collected by seines and trawls on the Alafia River within each segment on December 12, 1997. Black portion of each bar represents dead animals and grey portion represents live animals.

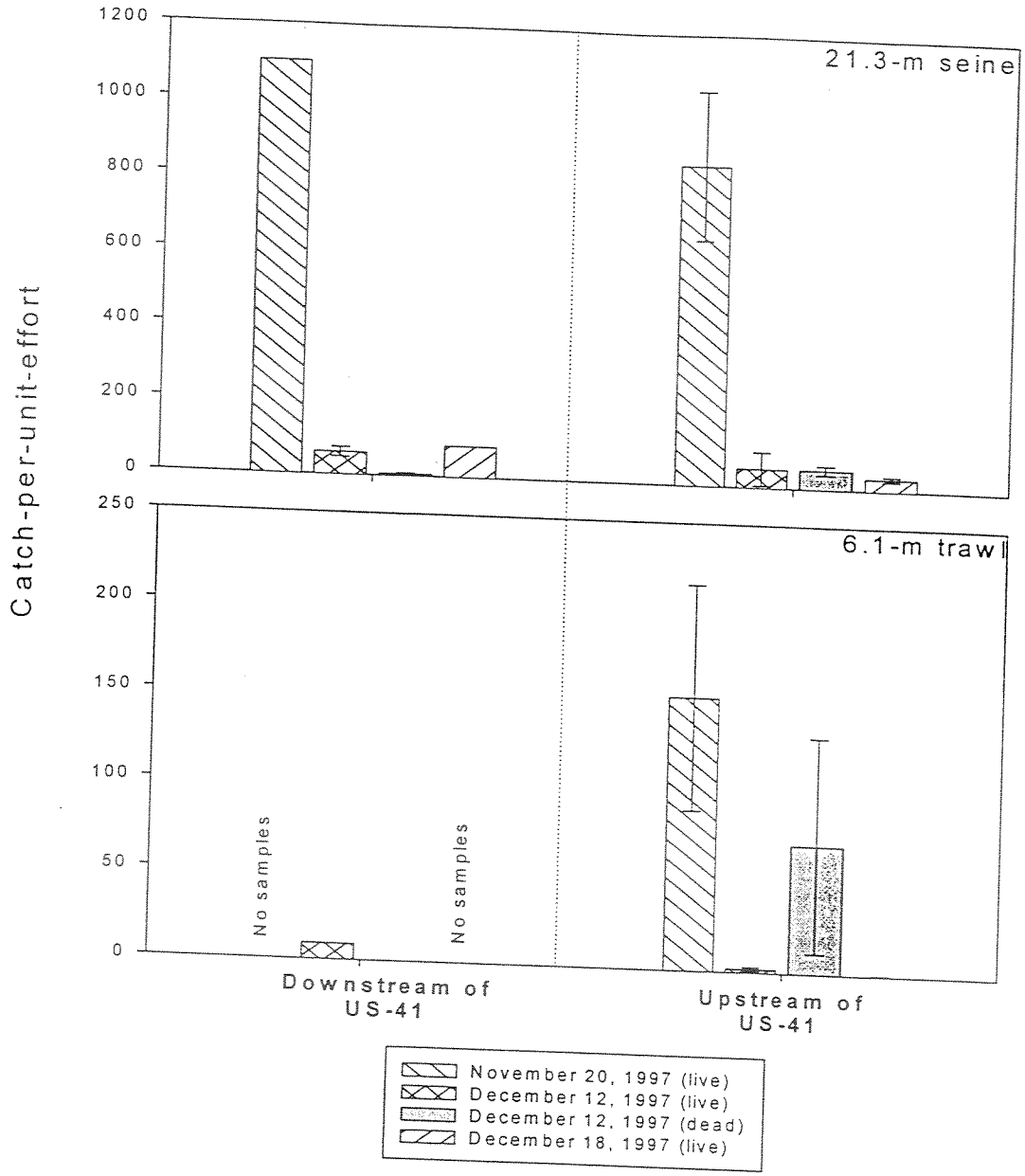

Figure 5. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for fish, blue crabs, and pink shrimp collected in FDEP/FIM seine and trawl samples from the lower Alafia River. Downstream of U.S. 41 = segment 1; upstream of U.S. 41 = segments 2-4. November 1997 represents pre-spill conditions; December 12, 1997, represents conditions as the acidic plume passed through the study area; and December 18, 1997, represents conditions soon after the neutralization of the plume. Dead animals were collected only on December 12. 1997. Means and standard errors calculated for simple-random sampling, by stratum.

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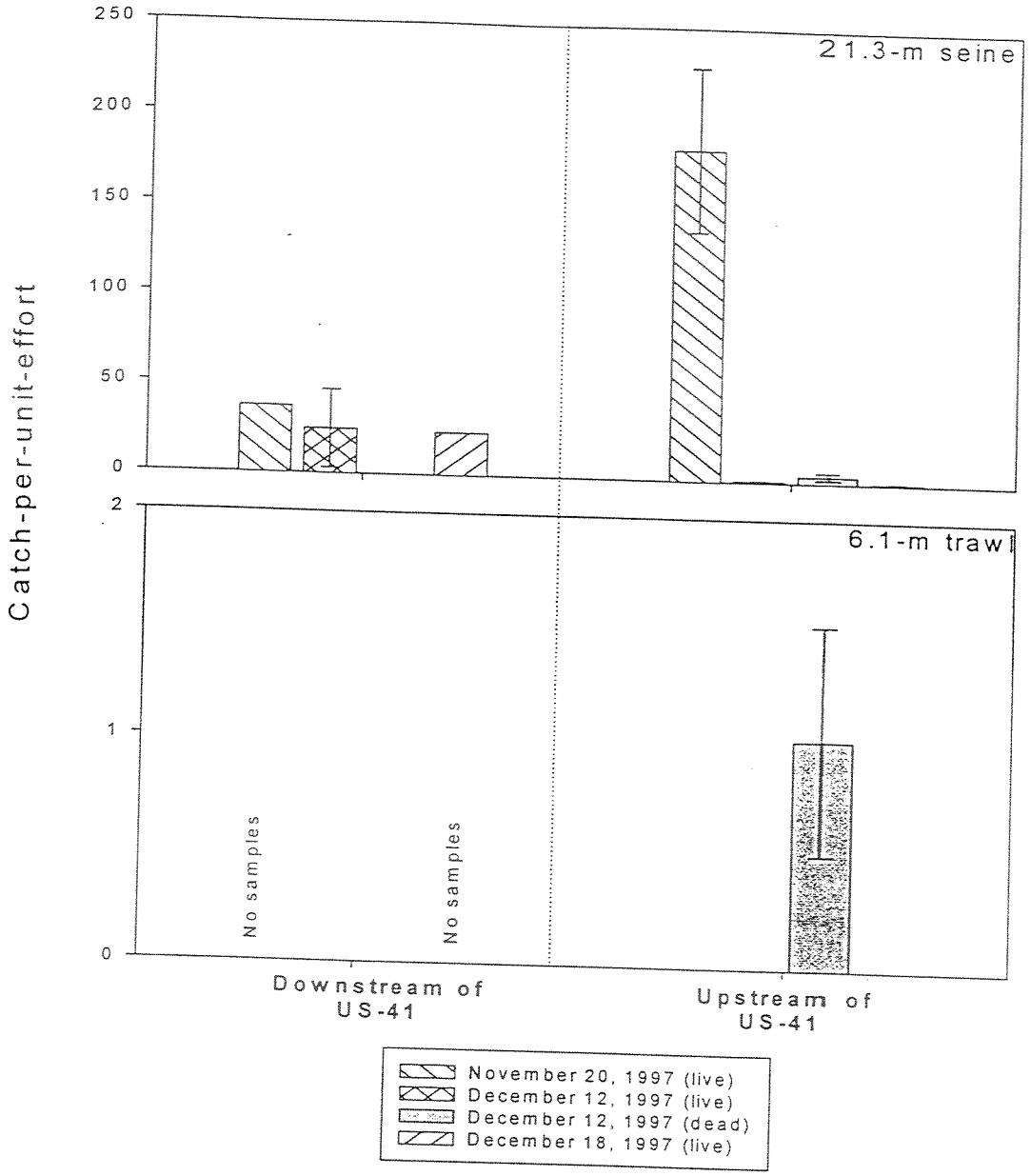

Figure 7. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for menidia collected in FDEP/FIM seine and trawl samples from the lower Alafia River. Downstream of U.S. 41 = segment 1; Upstream of U.S. 41 = segments 2-4. November 1997 represents pre-spill conditions; December 12, 1997, represents conditions as the acidic plume passed through the study area; and December 18, 1997, represents conditions soon after the neutralization of the plume. Dead animals were collected only on December 12, 1997. Means and standard errors calculated for simple-random sampling, by stratum.

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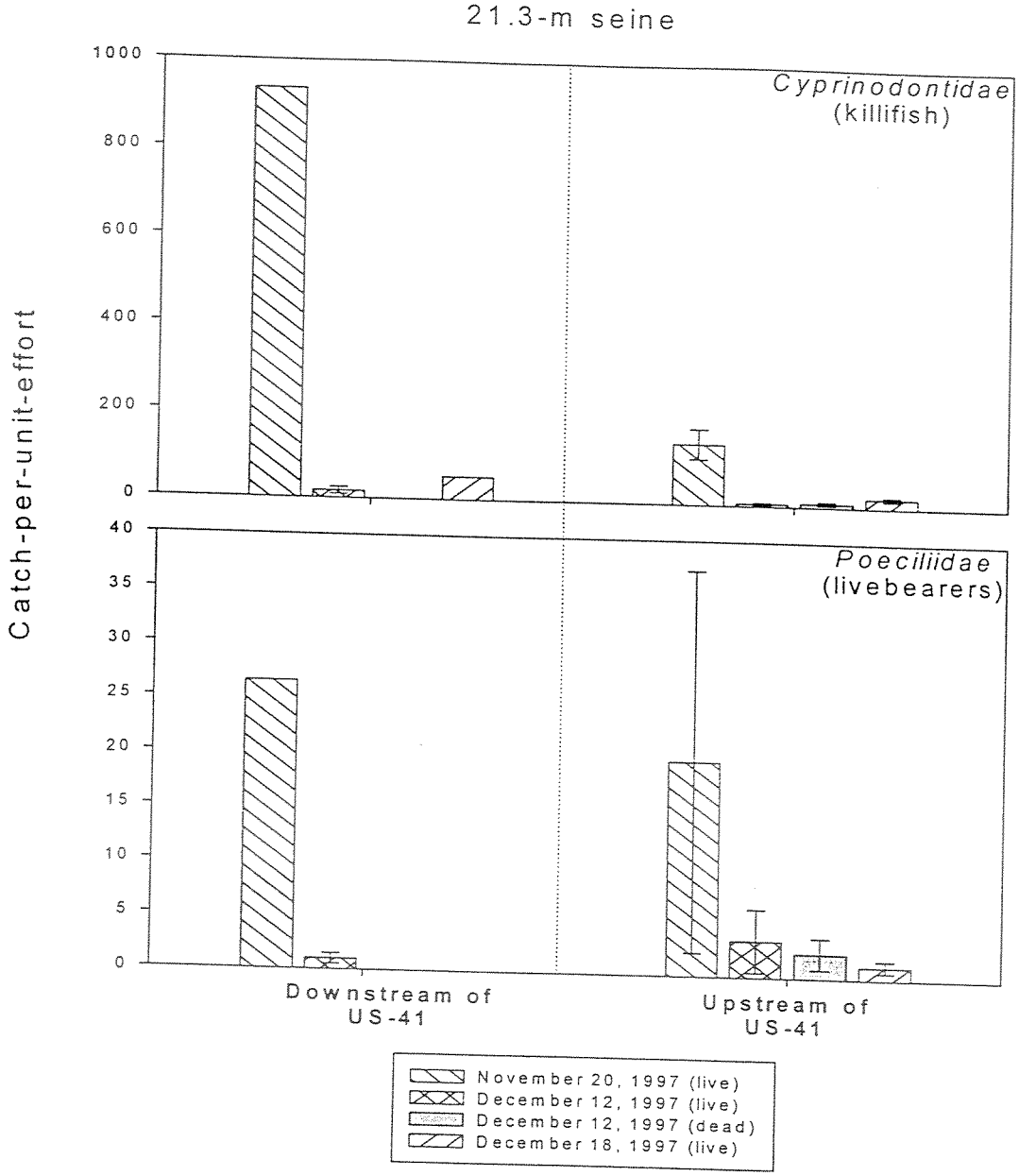

Figure 9. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for killifish and livebearers collected in FDEP/FIM seine samples from the lower Alafia River. Downstream of U.S. 41 = segment 1; Upstream of U.S. 41 = segments 2-4. November 1997 represents pre-spill conditions; December 12, 1997, represents conditions as the acidic plume passed through the study area; and December 18, 1997, represents conditions soon after the neutralization of the plume. Dead animals were collected only on December 12, 1997. Means and standard errors calculated for simple-random sampling.

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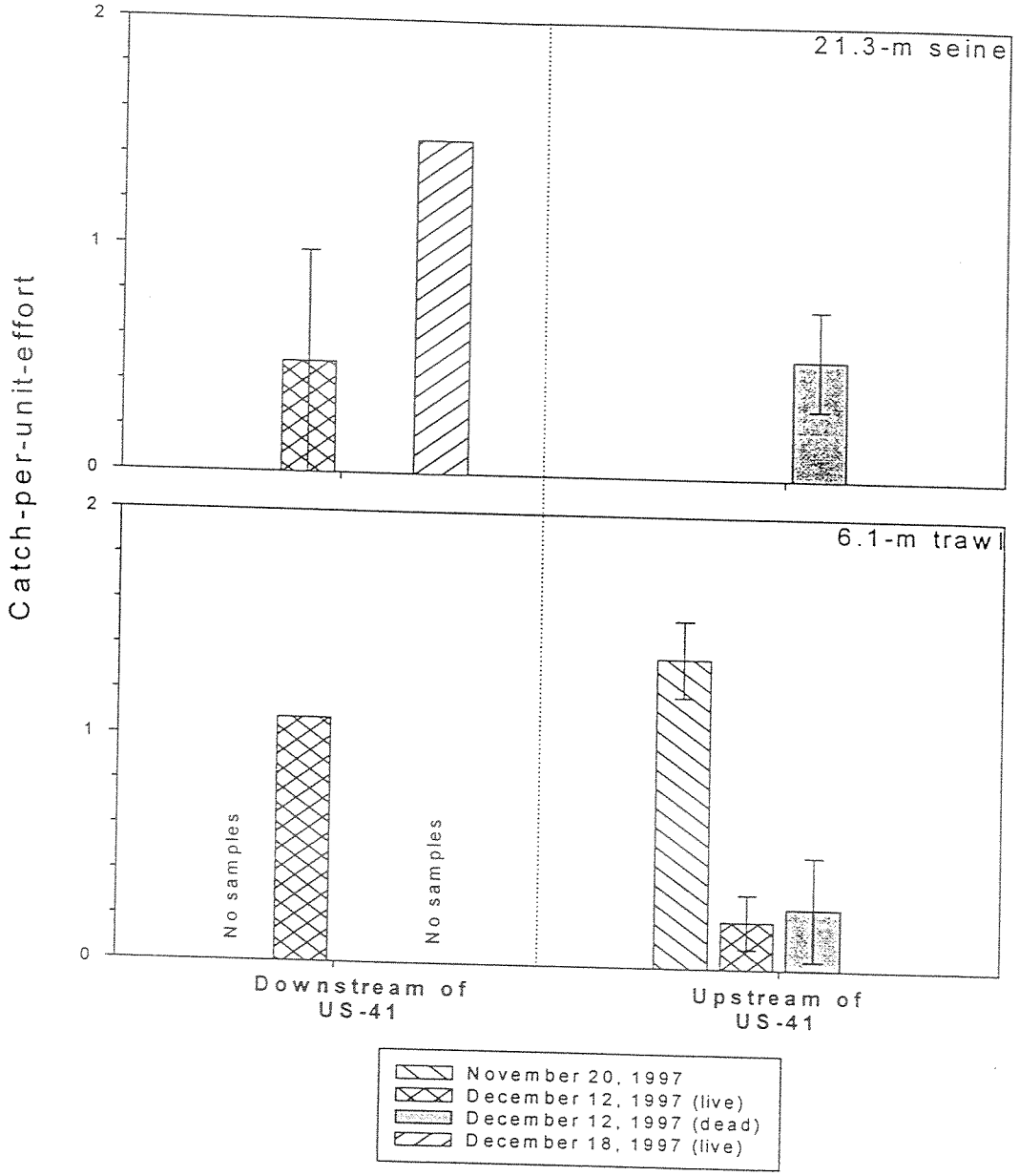

Figure 11. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for blue crabs collected in FDEP/FIM seine and trawl samples from the lower Alafia River. Downstream of U.S. 41 = segment 1; Upstream of U.S. 41 = segments 2-4. November 1997 represents pre-spill conditions; December 12, 1997, represents conditions as the acidic plume passed through the study area; and December 18, 1997, represents conditions soon after the neutralization of the plume. Dead animals were collected only on December 12, 1997. Means and standard errors calculated for simple-random sampling, by stratum.

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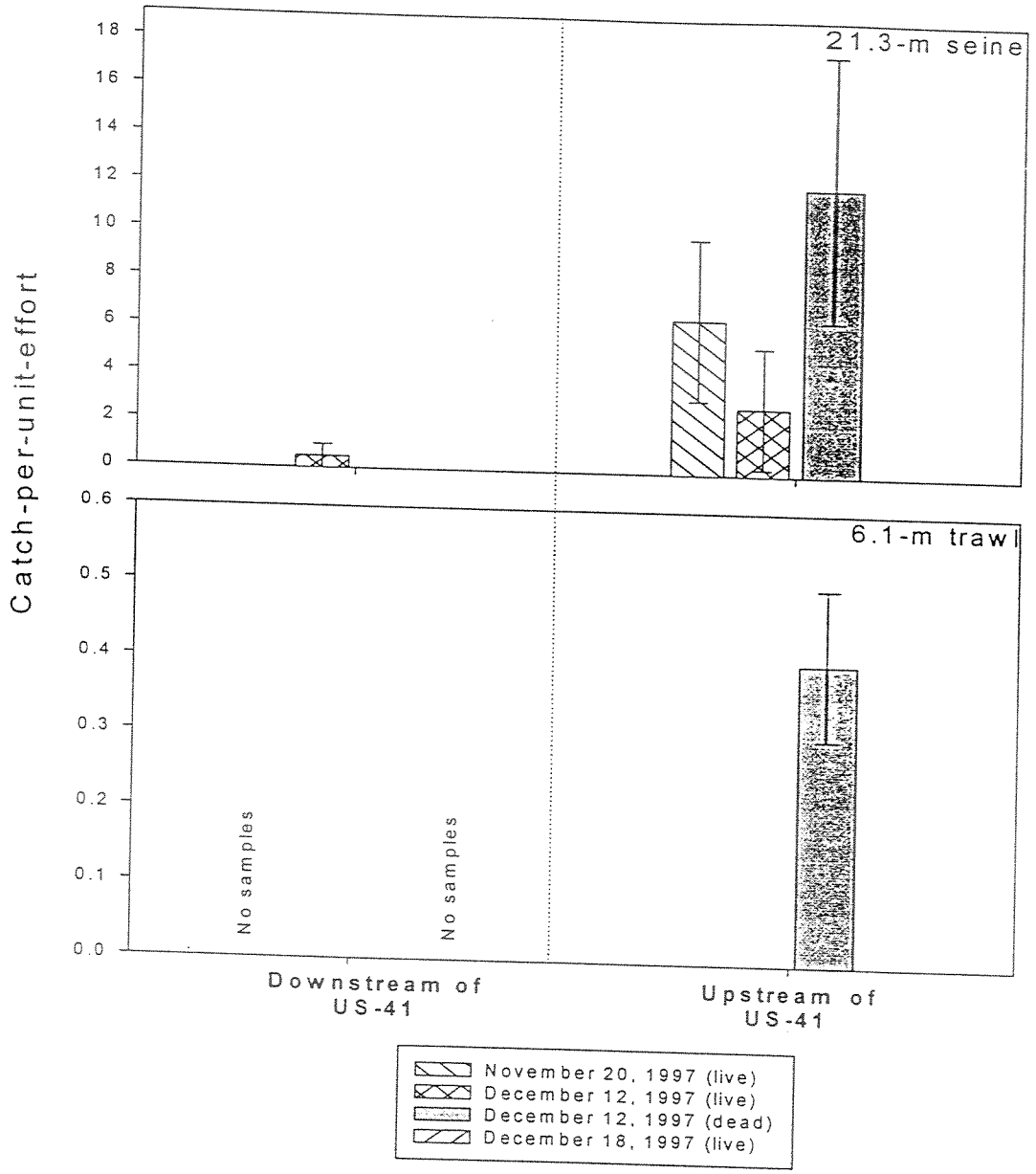

Figure 13. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for striped mojarra collected in FDEP/FIM seine and trawl samples from the lower Alafia River. Downstream of U.S. 41 = segment 1; Upstream of U.S. 41 = segments 2-4. November 1997 represents pre-spill conditions; December 12, 1997, represents conditions as the acidic plume passed through the study area; and December 18, 1997, represents conditions soon after the neutralization of the plume. Dead animals were collected only on December 12, 1997. Means and standard errors calculated for simple-random sampling, by stratum.

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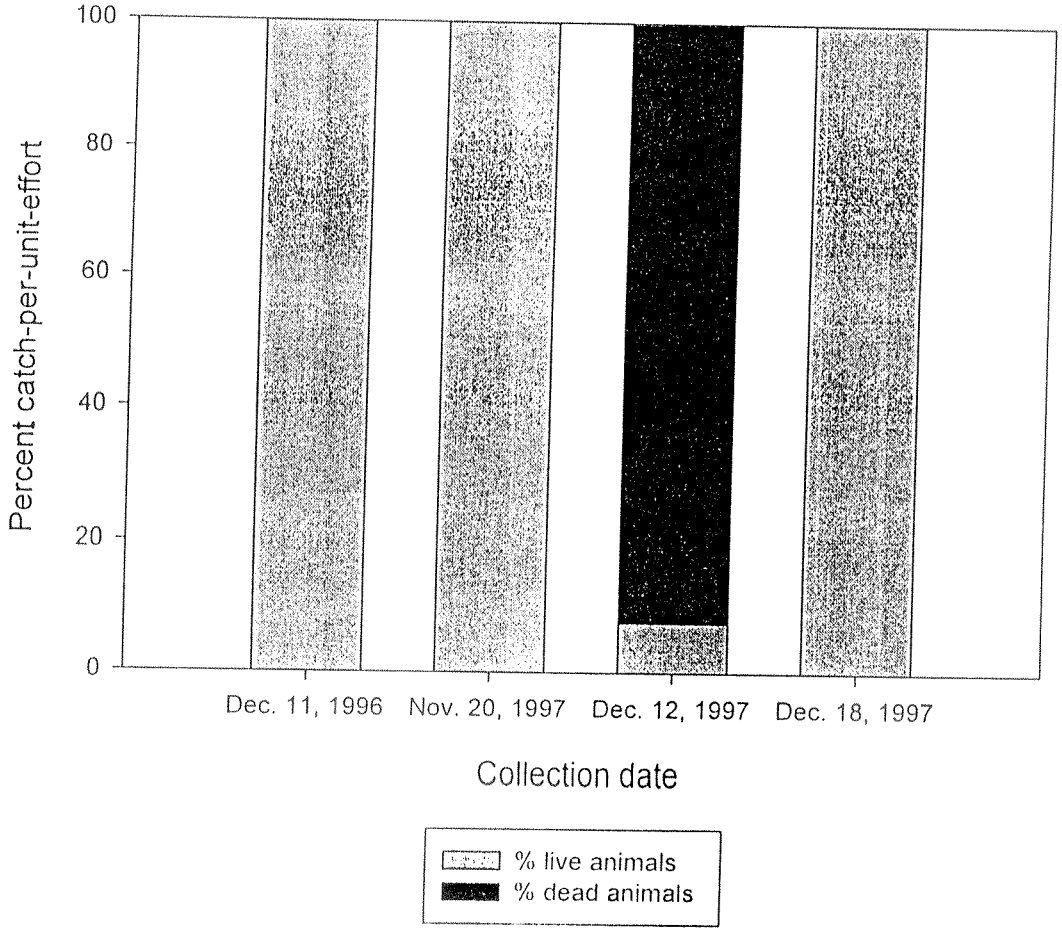

Figure 15. Percent catch-per-unit-effort (SRS means) of live and dead animals collected on the Alafia River on four dates.

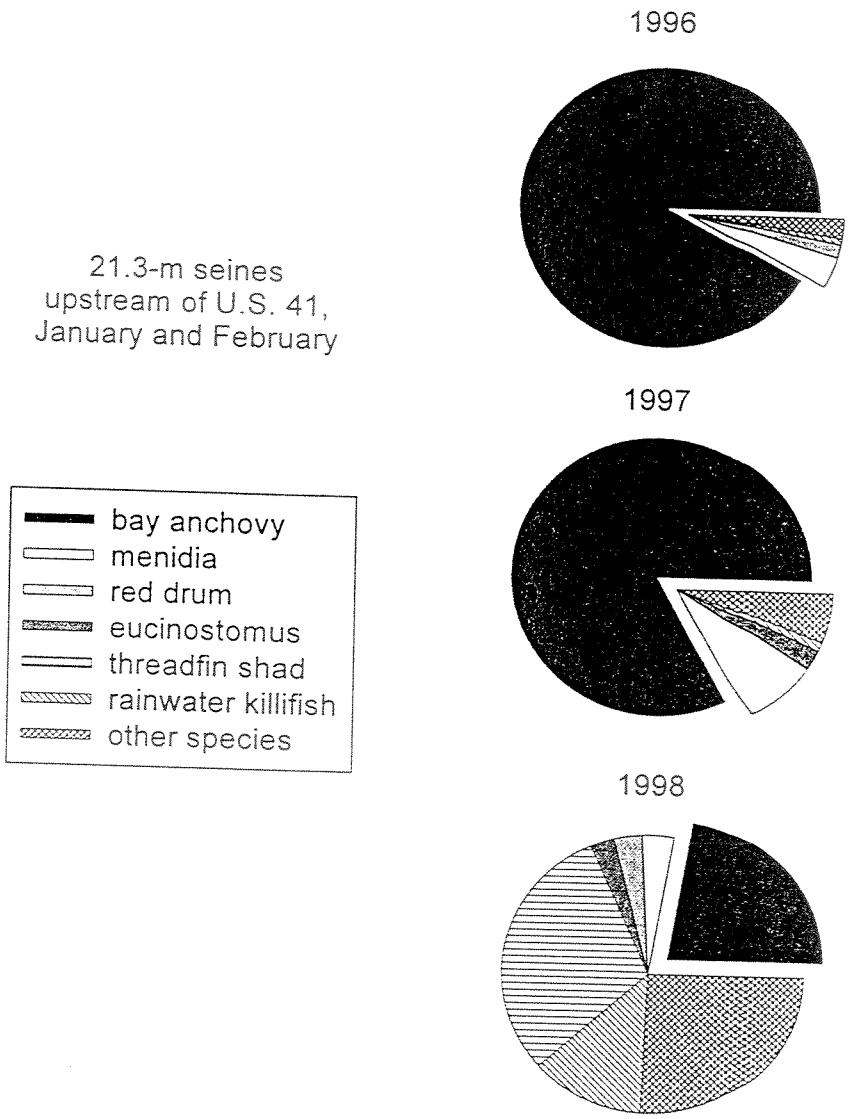

Figure 17. Relative abundances of fish, blue crabs, and pink shrimp collected in FDEP/FIM seine samples from segments 2-4 of the lower Alafia River during January-February of 1996, 1997, and 1998. The acidic plume passed through this area during December 1997.

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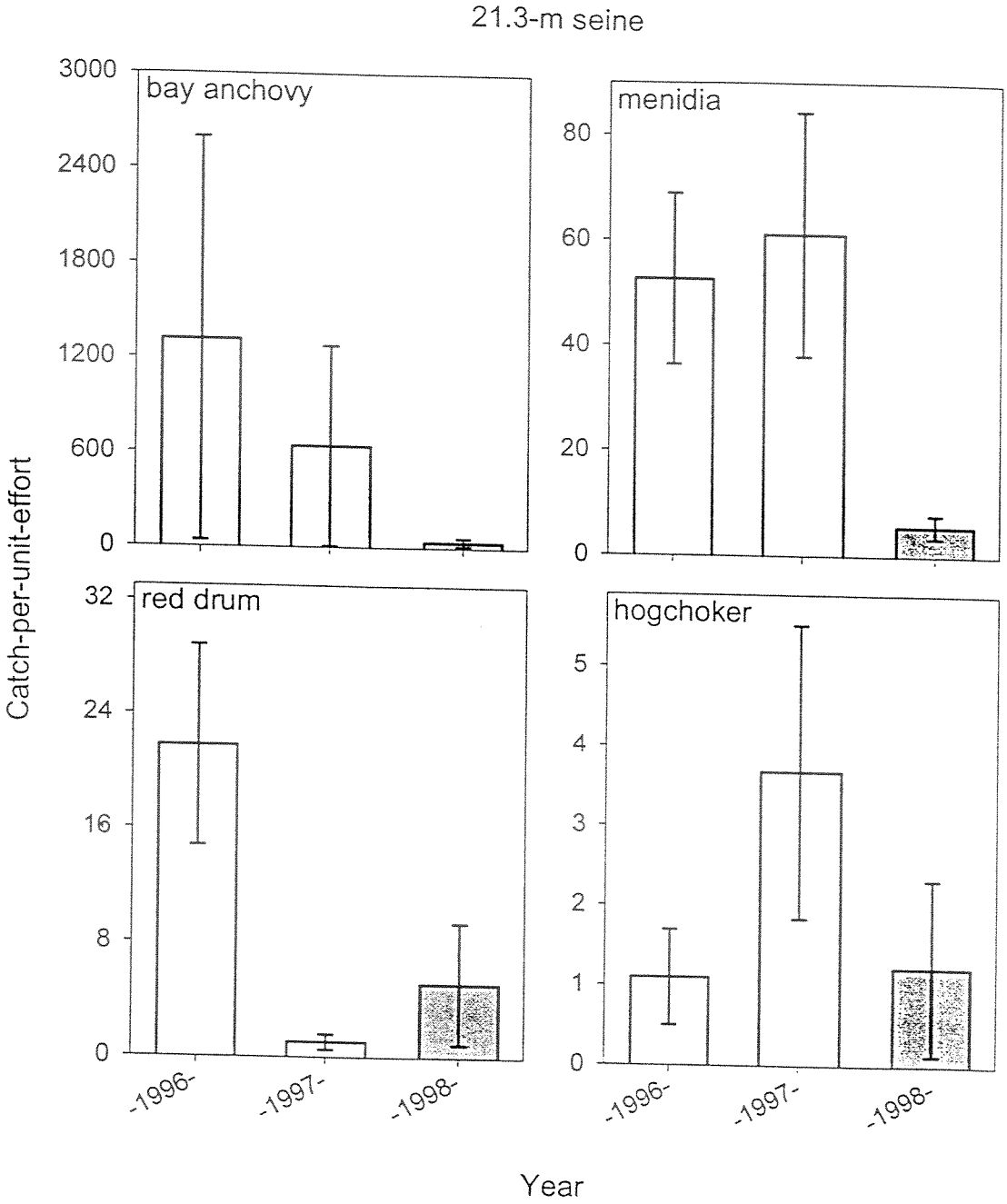

Figure 19. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for bay anchovy, menidia, red drum, and hogchoker collected in FDEP/FIM seine samples from segments 2-4 of the lower Alafia River during January-February of 1996, 1997, and 1998. The acidic plume passed through this area during December 1997. Means and standard errors calculated for simple-random sampling.

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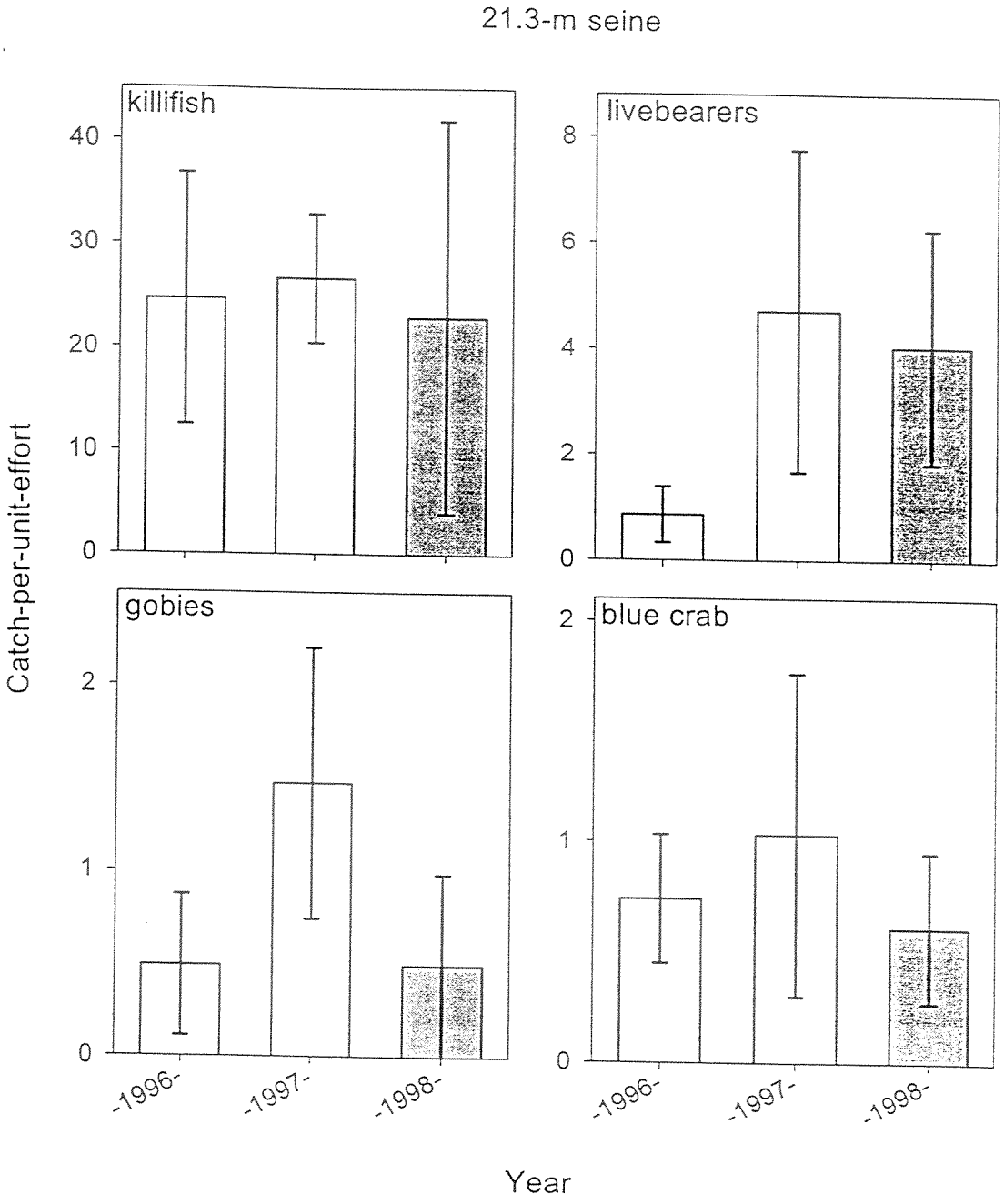

Figure 21. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for killifish, livebearers, gobies, and blue crab collected in FDEP/FIM seine samples from segments 2-4 of the lower Alafia River during January-February of 1996, 1997, and 1998. The acidic plume passed through this area during December 1997. Means and standard errors calculated for simple-random sampling.

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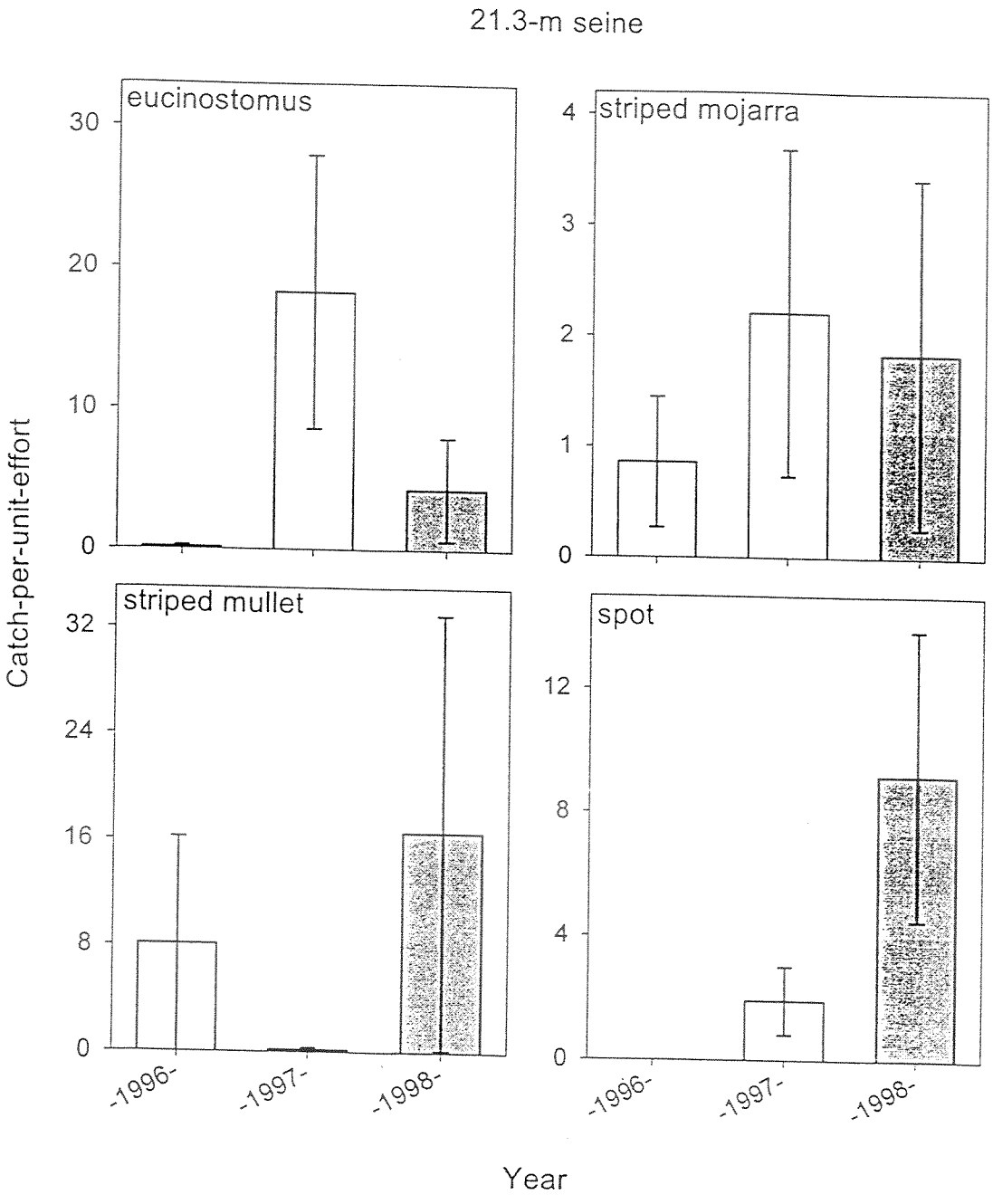

Figure 23. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for eucinostomus, striped mojarra, striped mullet, and spot collected in FDEP/FIM seine samples from segments 2-4 of the lower Alafia River during January-February of 1996, 1997, and 1998. The acidic plume passed through this area during December 1997. Means and standard errors calculated for simple-random sampling.

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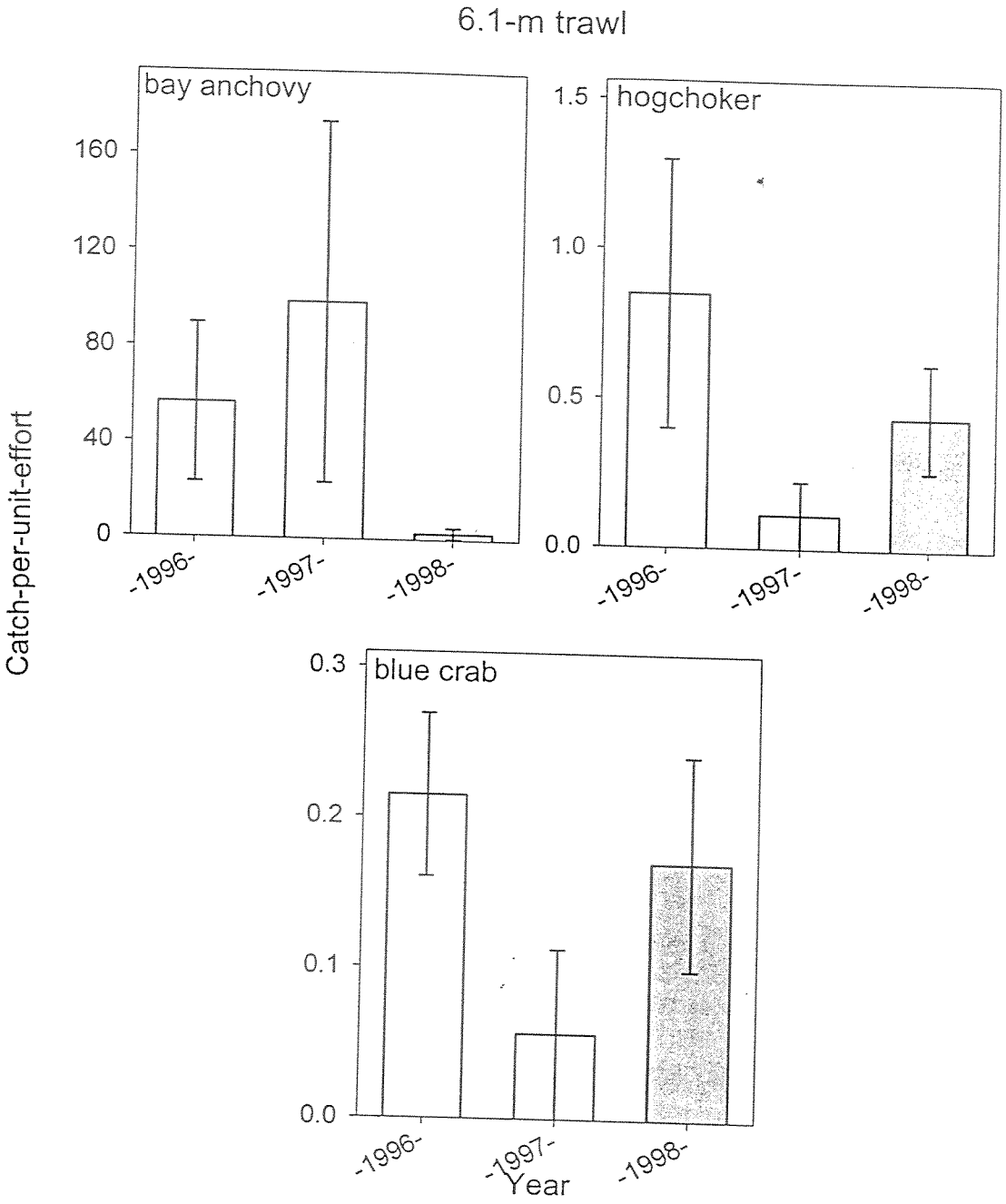

Figure 25. Mean (± 1 standard error) catch-per-unit-effort (number/100m²) for bay anchovy, hogchoker, and blue crab collected in FDEP/FIM trawl samples from segments 2-4 of the lower Alafia River during January-February of 1996, 1997, and 1998. The acidic plume passed through this area during December 1997. Means and standard errors calculated for simple-random sampling.

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